GROWTH OF OYSTERS, O. VIRGINICA, DURING DIFFERENT MONTHS

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Introduction

Although the American oyster, *Ostrea virginica,* is one of the most common bivalves of our Atlantic and Gulf Coasts, very little attention was given by past workers to various aspects of its growth, despite the fact that this field offers a large number of unanswered problems. For example, Moore (1898) in his voluminous article on the oyster devoted less than one page to a discussion of its growth. Churchill (1921) also confined himself to a few general statements on the growth of oysters under different environmental conditions. Yet, an understanding of the growth of oysters is of undeniable importance not only from a purely biological, but also from a practical, point of view because the oyster industry occupies one of the leading positions among the fisheries of the United States.

Nelson (1922) was perhaps the first to study more or less systematically certain phases of the growth of oysters. He measured and weighed a large group of New Jersey oysters in April and August of 1919 and again in March of 1920 noticing the increase in size and weight between the measurements. Loosanoff (1947) and his associates observed the increase in size of oysters of different ages grown during a three-year period in Milford Harbor, Connecticut. The oysters were measured once a year—in late autumn—to show the increase in size.

None of the observations made thus far was directed to study the relative increase in the size and volume of the oysters during each month of the year. This article presents the results of such studies which were carried on in Milford Harbor, Connecticut.

Winter Observations

Because it has never been satisfactorily shown whether New England oysters continue to grow during the hibernation period, experiments were carried on for three successive winters to give the needed answer.

Oysters were prepared for the experiments as follows: After the shells were cleaned of all foreign matter, the edges of the shells of each oyster were filed off to make it easier to notice new growth if any formed. The oysters were then individually numbered with small celluloid tags. Later the length, width, and depth of each oyster were measured with a vernier caliper reading to 0.1 mm. The length represented the greatest anterior-posterior dimension. The width was measured along the maximum dorso-ventral line, and the depth represented the maximum distance between the outer surfaces of the two shells.

For determining the volume of an oyster a modified Grave's (1912) method, consisting of measuring the quantity of water displaced by an oyster, was used.

The oysters were kept moist before immersion, to avoid a possible error in determining the volume, because dry shells usually absorb small quantities of water. The method was found simple but reliable, the measurements being accurate within one or two per cent.

The first experiment was begun with 80 three-year-old oysters. After the measurements were completed on December 7, 1944, the oysters were put into a large wire tray which was placed on the bottom of Milford Harbor at a depth of approximately 3 feet below the mean low water level. The water temperature on that date was 3.0° C. Soon after the tray was placed in the Harbor a layer of ice was formed and, therefore, the oysters could not be examined at frequent intervals.

The first examination was made on March 7, 1945 when the temperature of the water was still near 0.0° C. Examination of the edges of the shells showed that not in a single case was new growth formed. The final examination was made on March 20, when the water temperature was reaching 5.0° C., thus indicating that the end of the hibernation period was approaching. During this examination the length, width, depth, and volume of each oyster were re-measured and the data compared with those obtained for the same individual the preceding fall. Only three oysters died during the winter. The measurements of the living 77 oysters showed that they did not change in size or volume during the winter.

The second experiment was made during the winter of 1945–1946. A group of 120 oysters was placed in Milford Harbor at the beginning of the hibernation period and re-examined in March. All the oysters survived the winter but their shells did not increase in length, width, or depth.

The third and final experiment was conducted with 58 oysters between December 9, 1946 and March 14, 1947. In addition to the observations made during the two previous winters, the weight of each oyster was ascertained at the beginning and at the end of hibernation. The results of the March measurements showed that with the exception of one oyster which had part of its shell broken off, there was no change in length, width, depth, volume, or weight during the winter.

As a result of the observations made during three winters, we may conclude that in northern waters the shells of the oysters do not increase in size, volume, or weight during the hibernation period. However, our laboratory observations, which will be discussed in a later part of this article, showed that if the temperature of the water is kept well above the hibernation point, the oysters will continue to grow even in the middle of winter.

Observations During the Growing Period

The first experiments to determine the increase in the size and volume of the oysters during each month of the growing period were begun in the spring of 1944, but had to be discontinued in the middle of the summer because the new growth, which is almost as thin as cigarette paper and extremely brittle, broke off at the slightest touch. The experiments started in 1945 were also discontinued several months later for the same reason.

Finally, in 1946 the observations were successfully completed. On March 29, 1946, a group of 120 adult oysters was placed in a large wire tray attached to a float anchored in Milford Harbor. The float rose and fell with the tide but the position of the tray always remained approximately 3 feet below the surface of the water. Before placing the oysters in the tray they were individually numbered, measured, and their volumes determined.

The oysters were re-examined and re-measured at the end of each month; the last measurements were made during the last days of November when the water temperature was becoming low enough to induce hibernation. To keep the oysters out of the water as little as possible during the examinations they were handled in groups of ten, because such small groups could be measured and returned to the water within a few minutes. Also, by working with small groups it was easier to avoid breaking the shells.

Of the original group of 120 oysters, 109 were alive at the end of the experiment. The conclusions offered in this article are based upon the data obtained from these survivals. The ranges in length, width, depth, and volume of the oysters at the beginning of the observations were 68.2–107.5; 50.3–85.8; 22.5–40.0 mm.; and 40–104 cc. respectively. At the end of the experiments the ranges were 85.3–135.0; 66.5–107.6; 26.4–44.3 mm.; and 65–176 cc. The mean length, width, depth, and volume of the oysters for each month are given in Table I.

TABLE I

Mean with standard error of length, width, depth and volume of oysters at the end of each month during growing period of 1946, Milford Harbor

Month	Mean			
	Length in mm.	Width in mm.	Depth in mm.	Volume in cc.
March	88.2±0.766	65.4±0.519	30.0±0.314	63.7±1.438
April	88.7±0.799	65.6±0.554	30.0±0.319	64.8±1.519
May	93.8±0.823	71.0±0.604	30.0±0.319	65.7±1.518
June	98.1±0.886	79.4±0.766	30.0±0.319	69.0±1.531
July	103.1±1.001	82.5±0.763	31.0±0.309	73.6±1.675
August	106.0±0.95	83.8±0.788	32.1±0.329	84.1±1.893
September	109.6±1.034	86.0±0.786	33.2±0.352	93.0±2.243
October	110.4±1.06	86.3±0.8	34.1±0.37	97.2±2.464
November	110.8±1.084	86.3±0.8	34.6±0.365	99.3±2.596

In estimating the monthly increases of each variate, which represented the difference between the means of each two consecutive months, the total increase for the entire growing season was taken as 100 per cent, and the monthly gains were calculated in relation to it. The results are presented in Figures 1 and 2.

As already mentioned, the oysters of our area do not increase in size or volume during the hibernation period, which extends roughly from the beginning of December until the end of March. Monthly observations showed, however, that in April the shells of the oysters begin to grow, the mean increase in length for that month constituting 2.21 per cent of the total annual increment (Fig. 1). During May, June, and July the increase in length is most rapid, being 22.57, 19.03 and 22.12 per cent respectively. Thus, during these three months the oysters achieved approximately 63.7 per cent of their annual increase in length. The percentages for August, September, October and November were 12.83, 15.93, 3.54 and 1.77

respectively. As can be seen, the months of October and November contribute but little to the total annual increase in length.

An increase in the width of the oyster shells began in April, simultaneously with an increase in length, but terminated in October, a month earlier than the latter (Fig. 1 and Table I). It was extremely rapid in May and especially in June,

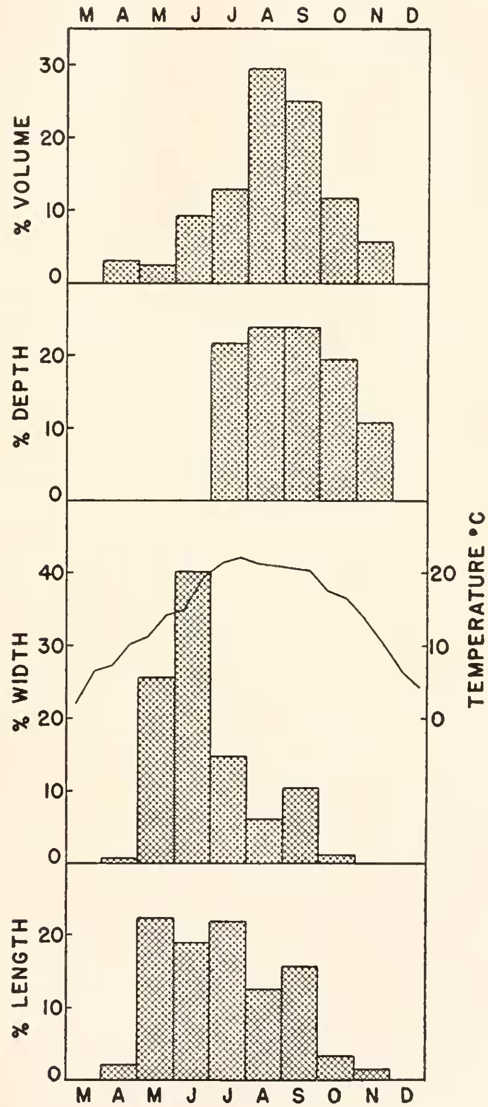

FIGURE 1. Per cent of increase in length, width, depth and volume of oysters during each month of the growing period. The total increase of each variate for the entire growing period, 1946 is taken as 100 per cent. Temperature curve is based upon semi-weekly records made at high water stages.

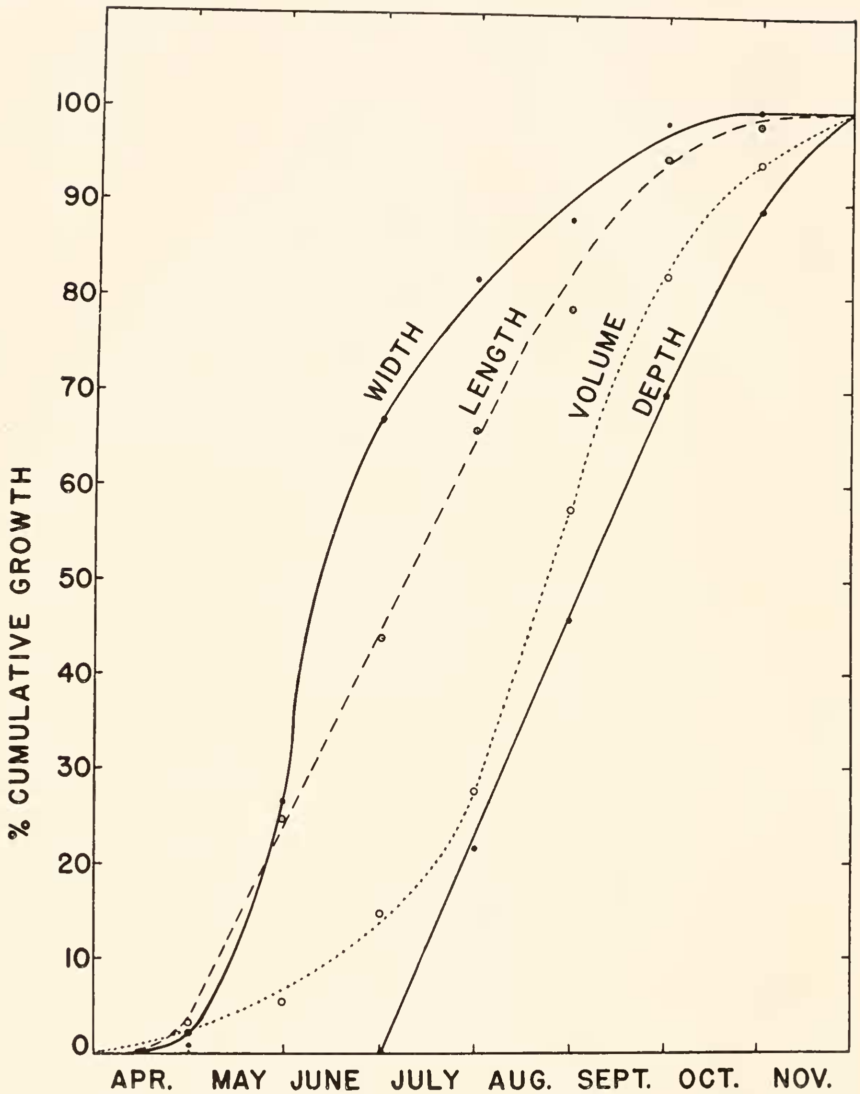

FIGURE 2. Per cent of cumulative growth in length, width, depth and volume of oysters recorded at the end of each month. The growth of each variate for the entire growing period of 1946 is taken as 100 per cent.

the latter month giving about 40 per cent of the total annual increase. In July, however, a sharp decrease was recorded. The decrease was even more pronounced during August.

Although the oysters increased in length, width, and volume during April, May, and June, the increase in the greatest depth was not appreciable until July (Figs. 1 and 2). During the first three months of the growing period the thinner parts of the shells became thicker, but this change was not reflected in the greatest depth, or thickness, of the oysters. Nevertheless, the observations on the increase in the greatest depth are of interest because they indicate, as do the studies of the increase in volume, that an increase in depth is largely achieved during the second part of the growing period.

The increase in volume of the oysters, the same as the increase in length, continued from April through November (Figs. 1, 2 and Table I). The greatest monthly increases were recorded during August and September, these two months giving approximately 55 per cent of the total annual increase in volume. As could be expected, the period of rapid increase in volume corresponded to that of greatest depth.

The marked increase in length and width of the oysters during May and June did not materially contribute to the increase in volume. This, of course, should be expected because newly formed shell-margins are very thin, displacing only small quantities of water.

Because the experimental oysters were individually numbered, it was possible to follow the increase in size of each individual from month to month throughout the entire growing period. This was done for two variates—length and volume. As usual, when working with a large number of animals, considerable individual differences were found. Nevertheless, the individual records showed the following interesting facts:

The maximum period during which oysters may grow in Milford Harbor is approximately of eight months' duration, extending from April to November, both months inclusive. However, only a small minority, comprising approximately 3 to 4 per cent of the entire group, grew during all the eight months, while for the majority of oysters the increase in length and volume was recorded only for five, six or seven months of the possible eight. About 3 per cent grew only three months and 10 per cent showed an increase in size for only four months, which were not always consecutive.

The chief increase in length and width of the oysters occurred during the first half of the eight-months' growing period, while the increase in the greatest depth and volume took place during the second half (Fig. 1). In this respect our observations are in agreement with those of Nelson (1922).

Not all the oysters began to grow in length and volume during the first month after the end of the hibernation period. Only about 48 per cent of the entire group increased in length in April, 49 per cent in May, while 3 per cent did not start growing until June. In volume, about 29 per cent began to show an increase in April, 40 per cent in May, 27 per cent in June, while 4 per cent did not show any increase until July.

Although it is true that we are usually concerned with the average animal, nevertheless, observations and records of unusually fast or slow-growing individuals are of significant biological value and interest because they may indicate that, within what may appear to be a homogeneous population, there may be distinct fast or slow-growing races. Some of the observations on individual oysters are given in the following paragraphs.

The greatest individual increment in length for the entire season was shown by oyster no. 22 which grew from 91.8 to 129.0 mm. in seven months, an increase of

37.2 mm. The smallest increase was shown by oyster no. 98 which grew from 77.6 to 85.3 mm., an increase of only 7.7 mm. This oyster grew in length only during two months out of a possible eight.

The greatest increase in volume for any individual was made by oyster no. 5, which increased from 104.0 to 176.0 cc., a total of 72 cc. in seven months. Oyster no. 17 showed an increase of only 8 cc., growing from 57.0 to 65.0 cc. in five months.

Individual records also made it possible to ascertain the maximum increase in length or volume of the fastest growing oysters for every month of the season (Table II). The largest monthly increase in length was made by oyster no. 90, which during July increased 15.2 mm., representing an increase of 17.9 per cent over the total length recorded at the end of June. During November the fastest growing oyster increased its length only by 3.4 per cent.

TABLE II

Greatest monthly increases in length or in volume shown by individual oysters. April–November, 1946. Milford Harbor

	April	May	June	July	Aug.	Sept.	Oct.	Nov.
				Length				
Oyster no.	81	104	78	90	82	21	22	26
Old size in mm.	78.0	90.3	94.3	84.7	110.9	119.1	121.5	114.6
New size in mm.	82.5	100.8	105.6	99.9	117.9	129.1	129.0	118.5
Increase in mm.	4.5	10.5	11.3	15.2	7.0	10.0	7.5	3.9
% Increase	5.8	11.6	12.0	17.9	6.3	8.4	6.2	3.4
				Volume				
Oyster no.	7	1	59	78	34	22	49	9
Old volume in cc.	73	78	73	72	79	98	106	128
New volume in cc.	78	82	84	87	99	127	122	136
Increase in cc.	5	4	11	15	20	29	16	8
% Increase	6.8	5.1	15.1	20.8	25.3	29.6	15.1	6.3

The greatest monthly increment in volume was made in September by oyster no. 22, which increased 29 cc. or 29.6 per cent over the volume recorded at the end of the preceding month.

It is significant that the greatest individual increases in length occurred during May, June, and July, that is, during the months when the group as a whole grew in length most rapidly. For the volume, both the greatest individual and group increments were noted in August and September (Fig. 1, Table II).

The records also show that the per cent of oysters increasing in length or volume varied considerably during different months. The increase was most common during July and August when almost all the oysters showed it, and the least noticeable in April and November.

Observations made on monthly growth of oysters in Milford Harbor suggest the following conclusions and deductions: Growth of the oysters, taken as a group, continued throughout the period extending from April to November, both months included, without definite interruption during the spawning season. This observation is in agreement with the conclusions of several investigators working with other lamellibranch mollusks. For example, Belding (1912) found that the hard-shell clam, *Venus mercenaria,* grows very fast during July and August when its spawning is in progress. During these two months the clams show approximately 45 per cent of the total annual increase in the length of the shell. Belding (1931) also found that the soft clam, *Mya arenaria,* which in Massachusetts waters spawns during June, July, and August, shows during these three months approximately 55 per cent of the annual increase in the length. Coe (1945, 1947) observed that the California bay-mussel, *Mytilus edulis diegensis,* also grows during the spawning period.

In other lamellibranchs, however, the rate of growth may be appreciably diminished during the spawning season. Belding (1910) noticed such a decrease in the bay scallop, *Pecten irradians.* Coe (1947) thinks that the decrease in monthly increments in length of the Pismo clam, *Tivela stultorum,* in August is due "to the requirements of the reproductive system and the successive acts of spawning."

In the case of oysters, Nelson (1922) found that *O. virginica* of the New Jersey coast grows rapidly until the spawning period but more slowly thereafter, while Orton (1935) observed two main periods of shell growth of *Ostrea edulis,* one in spring and one in autumn.

A very rapid increase in the mean length and width of the oysters of Milford Harbor occurred during May and June, i.e., during the period of most active gametogenesis for the oysters of this region (Loosanoff, 1942). Apparently, the process of development and accumulation of gametes did not interfere with the growth of the shell, at least as far as the increase in length and width was concerned. This conclusion is well supported by observations on oysters which are conditioned every winter in our laboratory to develop ripe eggs and spermatozoa (Loosanoff, 1945). The oysters are brought from the beds in the hibernating state and after being kept at room temperature for several hours are placed in trays with running warm water. In a month or less, depending upon the temperature of the conditioning trays, the oysters are ripe. Yet, during this period of extremely active gametogenesis the majority of the oysters grow rapidly in length and width, forming new shell-margins which quite often are over 1.0 cm. This proves, of course, that gonad development and rapid growth of shell may proceed simultaneously.

Mass spawning of the experimental oysters was observed during the last few days of June. There is no doubt that these oysters continued spawning during July and that many of them completed spawning during that month. The latter point was ascertained by opening Milford Harbor oysters not used in the experiment. Therefore, we concluded that since July was the month of most active spawning and since the increase in length during that month was very rapid, it is apparent that the spawning activities did not sharply affect the rate of increase in the shell length. In this respect our conclusions differ from those of Orton (1928) who reported that the rate of growth of the European oyster, *O. edulis,* is considerably slowed down during the breeding period.

It may be tempting to explain the slowing of the growth in width of our oysters during July by ascribing it to the spawning activities. Such an explanation, however, does not appear to be very conclusive because three other variates showed an increase during that month (Fig. 1). Even if the rate of increase in width during

July was considerably slower than that observed in June, it still was comparatively rapid, occupying the third position among the eight months of the growing season. Moreover, our laboratory experiments on the conditioning of oysters for spawning in the winter gave us additional proof that spawning does not stop, or seriously decrease, the rate of shell growth. For example, in February, 1949, a group of 105 oysters was brought from Long Island Sound, where the water temperature was below 5.0° C., and after being measured was placed in warm running sea water at 25.0° C. At the end of the ninth day at this temperature the oysters spawned. Some of the spawning oysters had already at that time a new shell growth which measured over 1.0 cm. After spawning, the oysters continued to form a new shell for some time.

The slowing down of the rate of growth in length and width during August also should not be attributed to the spawning activities because of the considerations presented above. Furthermore, spawning was almost completed during July. Perhaps the slow growth could be more logically associated with the post-spawning stage, during which emaciated oysters are, presumably, not in condition to divert much of their energy into building new shell substance. This assumption is again easily invalidated because of the pronounced acceleration in the increase in volume noticed in August and in early September (Fig. 1).

There are some indications of possible physiological antagonism between the growth of oysters and the process of accumulation of glycogen in their tissues, a phenomenon commonly known as "fattening of oysters." In our waters, chief accumulation of glycogen in the meats of oysters occurs between the completion of spawning and until hibernation, thus covering a period of approximately three months, namely, September, October, and November. During this period the rate of increase in size and volume of oysters progressively diminishes (Figs. 1 and 2). Whether this decrease is due to the true antagonism of the different physiological functions, or merely reflects the changes occurring in the surrounding water, remains at present undetermined.

The changes of the water temperature and the monthly rates of growth of oysters showed only a partial relationship. It is true that the increase in length and width of the shells recorded in April, May and June was accompanied by a steady rise in temperature (Fig. 1). In July, however, the rate of increase in the width markedly decreased, although the temperature remained above 20.0° C., but such a presumably favorable condition was not reflected in the rate of increase in length and width. The comparatively slow rate of growth in length and width observed during October cannot be explained by the unfavorably low temperature, because during that month the average temperature was not lower than that recorded for May and the early part of June when the shells grew so rapidly.

A much clearer relationship was found between the monthly increments in volume and the changes in water temperature (Fig. 1). In spring and early summer the monthly increments increased simultaneously with the increase in temperature. The period of the most rapid monthly increases in volume roughly corresponded to the period of maximal seasonal temperature, while in the fall both showed a gradual decline.

In connection with these studies it was thought desirable to determine by experimental means the rate of growth of groups of oysters kept at different temperatures. This was done in the winter time because it was easier then to maintain in the laboratory the desired temperatures merely by mixing definite quantities of cold and warm running sea water.

The warm sea water system, which is operated in our laboratory during the cold season, is regulated by a series of thermostats which control the temperature of the outflowing water. The temperature of our cold water is also very uniform. Therefore, in the winter time water of any temperature within the range of about 5.0° to 35.0° C. can be had by using constant level jars of cold and warm water and by regulating by stopcocks the flow from these jars into a mixing chamber until the desired temperature is obtained. From the mixing chamber the water is flowed into the trays or aquaria containing the oysters.

In the middle of February a shipment of four-year-old oysters, consisting of individuals of approximately the same size, was brought from the beds of Long Island Sound and placed for several hours in sea water of about 8.0° to 9.0° C. to let the oysters come out of hibernation. Then they were divided at random into four groups each containing 105 animals. After determining the average length and width of each group (Table III), the oysters were placed in trays with running water the temperature of which was brought up and then steadily maintained at approximately 10.0°, 15.0°, 20.0° or 25.0° C. All the trays were receiving the same quantity of water.

TABLE III

Average increase in length and width of oysters kept at temperatures of 10.0, 15.0, 20.0 or 25.0° C. from February 15 to March 16, 1949

Temperatures	10.0° C.		15.0° C.		20.0° C.		25.0° C.	
	L.	W.	L.	W.	L.	W.	L.	W.
Original measurements 2/15/49	92.1	70.3	91.5	68.6	92.5	70.1	94.0	70.1
Final measurements 3/16/49	93.4	71.3	99.9	76.0	100.1	77.3	98.5	73.2
Increase in mm.	1.3	1.0	8.4	7.4	7.6	7.2	4.5	3.1
% Increase	1.4	1.4	9.2	10.8	8.2	10.3	4.8	4.4

A month later the oysters were again measured (Table III). The 15.0° C. group grew best, showing at the end of the experiment an increase of 9.2 per cent in length and 10.8 per cent in width of shell. The maximum increase in length shown by the fastest growing oyster of this group was 21.0 mm. The growth of oysters kept at 20.0° C. was almost as fast as that of the 15.0° C. group. However, the 25.0° C. group grew much more slowly than the two above mentioned, and the 10.0° C. group showed only a slight increase in size. The maximum increase in length attained by the fastest growing oysters of the 25.0° and 10.0° C. groups was 14.0 and 5.0 mm. respectively.

In the 15.0° C. group all the oysters showed new growth and in 20.0° C. only one individual did not form new shell. In the 10.0° and 25.0° C. groups, however, many oysters did not grow.

Examination of the new shell growth showed that its character was different in the different groups. In the lowest group the new shell was, at the end of the experiment, still transparent, soft and flexible. In the 15.0° C. group, however, the new shell substance was already becoming harder and more brittle, and only the most recently formed part, confined to the edges of the shell, was still soft and flexible. This condition was even more pronounced at higher temperatures but, nevertheless, even in those groups many oysters were still forming new growth during the last days of the experiment.

Thus, under the conditions under which the experiment was run, the oysters grew most rapidly at temperatures of 15.0° and 20.0° C. Therefore, the optimum temperature range for their growth was either confined between these two temperatures or, what is more probable, extended a degree or two outside these two limits giving a range from approximately 13.0° to 22.0° C. It is interesting that the rapid increase in length and width shown in the spring and early summer by the oysters grown in Milford Harbor took place during May and June, in other words, when the water temperature was within the range given above (Fig. 1).

Our laboratory observations on the growth of oysters at different temperatures were, however, of too short a duration to find whether, if the experiment had been continued for several more months, the growth of each group would have proceeded at its original rate or would have shown some important changes. For example, it is possible that if the experiment had been prolonged, the rate of growth of the fast growing groups of 15.0° and 20.0° C. would have gradually decreased and, perhaps, eventually stopped, while the growth of the 10.0° C. group would have proceeded at the same or even at a somewhat faster rate than that shown during the first month of observation. It is planned to find the answer to this question in the near future.

With our present knowledge, it is impossible to estimate accurately the effect of food upon the growth of oysters. In a basin, such as Milford Harbor, where the tidal currents are swift and where the difference between high and low water levels may be as much as 9 feet, the quantity and quality of the material suspended in the water flowing over the oysters changes continuously. Even if it were possible to collect samples continuously, such samples would be of only limited value because many forms composing nanno and ultraplankton disintegrate almost immediately after collection. Thus, even if the quantity of material suspended in the water could be somehow determined, the quality of part of it would remain unknown.

Perhaps the greatest handicap facing the students of the role of food upon growth and other phases of the physiology of oysters is our lack of definite knowledge as to what really is the food of these mollusks. A full discussion on this subject is not the purpose of this article—those interested are referred to a summary published recently (Loosanoff and Engle, 1947). Briefly, however, while one school of investigators assumes that living plankton is the main ingredient of the oyster diet, the second school led by Coe (1945, 1947) is of the opinion that most of the nutrition of oysters, clams, mussels and other filter-feeding bivalve mollusks is derived from the intra-cellular digestion of particles of detritus originating from the disintegrated cells of marine animals and plants. Coe's conclusions appear to be well supported but, nevertheless, the issue is still debatable and not finally solved. As long as it remains in this stage, and as long as the value of different components of plankton and detritus are undetermined, it will remain impossible to formulate intelligently the relationships between the quantities or qualities of food present in the water over the oyster beds and the various aspects of the physiology of oysters or other mollusks closely related to them.

The difficulties of solving these problems are further complicated because oysters, and probably some other lamellibranchs, can feed efficiently only when the concentration of plankton (Loosanoff and Engle, 1947) or turbidity-creating substances as detritus or silt (Loosanoff and Tommers, 1948) do not exceed certain thresholds. If such thresholds are exceeded, the normal existence of mollusks becomes impossible. Thus, in addition to determining what organisms or materials constitute oyster food, it will also be necessary to determine their optimum concentrations in relation to the feeding and growth of oysters.

It should also be mentioned that a rapid increase in length and width of shell does not necessarily indicate that the oysters are growing under favorable conditions. For example, on several occasions at Milford Laboratory the oysters discarded after being used in the experiments were crowded in small aquaria through which only a trickle of water passed. Yet, within a short time some of them showed new shell growth. This growth was formed despite the fact that the oysters were not receiving enough food and that the water in which they were kept contained large quantities of waste products. Similar observations were made on oysters kept in heavy concentrations of micro-organisms, such as Chlorella and Nitzschia, which interfered with the normal feeding. The oysters eventually died (Loosanoff and Engle, 1947) but, nevertheless, even if their meats were emaciated, new shell growth was forming shortly before their death. These observations suggest that the factors involved in the growth of oysters are rather complex and at present not well understood.

The data and the conclusions on the monthly increase of oysters offered in this article are based upon only one year of observations. It is possible that during some years, when conditions are unusually favorable and the water temperature is considerably above normal during March or December, a slight increase in the size of the shells may be noted during these months. It is also possible that the monthly increases of the variates in different years would differ somewhat from those shown in our Figure 1. Nevertheless, it is believed that such variations would not basically change the trend of growth during the year.

Summary

1. The oysters grown in Milford Harbor did not increase in size, volume or weight during the hibernation period. However, if by some artificial means the temperature of the water is kept above the hibernation point, the oysters will continue to grow in the laboratory even in the middle of winter.

2. The maximum period during which oysters may grow in Milford Harbor is approximately of eight months' duration extending from April to November, both months inclusive. Only a small minority comprising approximately 3 to 4 per cent grew during all the eight months, while the majority grew only for five, six, or seven months. Some oysters did not start growing in length until June, and in volume until July.

3. The increase in length was most rapid during May, June, and July, representing 22.57, 19.03 and 22.12 per cent respectively of the total annual increment. The growth in width was especially rapid in June, giving 40 per cent of the total annual increase. The increase in the greatest depth was not appreciable until July.

4. The increase in volume continued from April through November; the greatest

monthly increases were recorded during August and September; these two months combined gave approximately 55 per cent of the annual increase in volume.

5. The increase in size was most common during July and August, when almost all the oysters showed it, and least noticeable in April and November.

6. The process of gametogenesis did not interfere with the growth of the shell, at least as far as the increase in length and width was concerned.

7. The spawning activities did not adversely affect the rate of increase in length and in volume.

8. The chief increase in length and width of the oysters occurred during the first half of the growing period, while the increase in depth and volume was most pronounced during the second half.

9. Changes in the rate of growth in length and width showed only partial relationship with changes in the water temperature. However, a rather definite relationship was found between the changes in the rate of increase in volume and changes in the water temperature.

LITERATURE CITED

Belding, D. L., 1910. A report upon the scallop fishery of Massachusetts. *The Commonwealth of Massachusetts, Dept. of Fisheries and Game,* 1–150.

Belding, D. L., 1912. A report upon the quahaug and oyster fisheries of Massachusetts. *The Commonwealth of Massachusetts, Marine Fisheries Series No. 2,* 1–134.

Belding, D. L., 1931. The soft-shelled clam fishery of Massachusetts. *The Commonwealth of Massachusetts, Marine Fisheries Series No. 1,* 1–65.

Churchill, E. P., 1921. The oyster and the oyster industry of the Atlantic and Gulf Coasts. *U. S. Bur. Fish., Document No. 890, Appendix 8 to Report U. S. Comm. Fish.,* 1–51.

Coe, W. R., 1945. Nutrition and growth of the California bay-mussel (Mytilus edulis diegensis). *Jour. Exp. Zool.,* **99**: 1–14.

Coe, W. R., 1947. Nutrition, growth and sexuality of the Pismo clam (Tivela stultorum). *Jour. Exp. Zool.,* **104**: 1–24.

Grave, C., 1912. Fourth report of the board of shell fish commissioners of Maryland, 1–376.

Loosanoff, V. L., 1942. Seasonal gonadal changes in the adult oysters, Ostrea virginica, of Long Island Sound. *Biol. Bull.,* **82**: 195–206.

Loosanoff, V. L., 1945. Precocious gonad development in oysters induced in midwinter by high temperature. *Science,* **102**: 124–125.

Loosanoff, V. L., 1947. Growth of oysters of different ages in Milford Harbor, Connecticut. *Southern Fisherman,* **7**: 222–225.

Loosanoff, V. L. and J. B. Engle, 1947. Effect of different concentrations of micro-organisms on the feeding of oysters (O. virginica). *U. S. Dept. of the Interior, Fish and Wildlife Service, Fishery Bulletin 42,* 31–57.

Loosanoff, V. L. and F. D. Tommers, 1948. Effect of suspended silt and other substances on rate of feeding of oysters. *Science,* **107**: 69–70.

Moore, H. F., 1898. Oysters and methods of oyster-culture. *Rept. U. S. Com. Fish and Fisheries for the year ending June 30, 1897,* **23**: 263–340.

Nelson, T. C., 1922. *Rept. N. J. Agr. Exp. Sta. for the year ending June 30, 1921,* 287–299.

Orton, J. H., 1928. On rhythmic periods in shell-growth in O. edulis with a note on fattening. *Jour. Mar. Biol. Assoc.,* **15**: 365–427.

Orton, J. H., 1935. Laws of shell-growth in English native oysters (O. edulis). *Nature,* **135**: 1–340.